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The Fossil Cypraeidae of the Fruitville Member (Unit 2) and Kissimmee River Valley Equivalent, Tamiami Formation of Southern Florida: (Mollusca: Gastropoda: Cypraeidae)

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ABSTRACT Unit 2 was the last member of the Tamiami Formation of the Late Piacenzian Pliocene. Its ending signaled the commencement of a two stage extinction event. The first stage wounding event resulted in the disappearance of the *Akleistostoma* (Gardner, 1948), *Calusacypraea* (Petuch, 1996) and *Pseudadusta* (Petuch, 2004) genera and the end of the Tamiami Formation.

KEYWORDS Tamiami Formation, Fruitville Member (Unit 2), Unit 2 equivalent, *Akleistostoma*, *Siphocypraea*, *Pahayokea*, *Calusacypraea*, *Okeechobea*, *Pseudadusta*, Myakka Lagoon System (Myakka), Kissimmee Embayment, Kissimmee River Valley (Kissimmee), Caloosahatchee Strait, Loxahatchee Strait, Okeechobee Plains, Immokalee Reef Tract, Everglades Pseudoatoll.

INTRODUCTION

The transition from Unit 3 to Unit 2 time was marked by a continuation of falling sea levels, to levels below Unit 3 time, as temperatures again fell. Lower sea levels and temperatures resulted in altered molluscan habitats producing new species in a sequential evolutionary radiation as the populations adapted to these habitats. The ten Fruitville Member (Unit 3) Cypraeidae species in four genera of the Myakka Lagoon System were followed by a like number of new species in the same four genera, which evolved in Fruitville (Unit 2) time. In the Kissimmee River Valley, the four Unit 3 equivalent species in two genera were followed by seven new species in three genera, which emerged in that area. In the Immokalee Reef Tract (Unit 2), one new species has been recorded and described. While *Okeechobea* (Petuch, 2004) Unit 3 equivalent species have not been recorded from Kissimmee, two species of the genera have been recorded from Unit 2 equivalent strata.

Unit 2 marks the end of the Tamiami Formation and the last Cypraeidae radiation of the late Piacenzian Pliocene. For the Cypraeidae genera this meant either adaptation or extinction.

Fruitville (Unit 2) Myakka Lagoon System

In the western Myakka estuary, Fruitville Unit 2, present day Sarasota region, the mangrove forests were reduced to the extent that they were no longer a viable habitat for molluscan populations. The iconic Unit 3 pearly mussel *Perna conradiana* (d'Orbigny, 1852) beds that formed in the large quartz sand intertidal shoals were overlain by beds of *Chama gardnerae* Olsson and Harbison, 1953 (cemented saltwater clams). As with the *P. conradiana* beds, patches of sea grass were scattered between the *Chama* beds and hosted many of the Unit 2 Cypraeidae. The mud flats remained a viable Cypraeidae habitat and adjoined the sea grass patches.

The sea grass patches were associated with *Siphocypraea (Seminolecypraea) alligator* Petuch, 1994 (Figure 1F) and *Calusacypraea*

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(Myakkacypraea) schnireli Petuch, 2004 (Figure 1G) as their preferred habitat. They also hosted *Pseudadusta marilynae* (Petuch, 1994) (Figure 1H).

Myakka Cypraeidae populations remained isolated in Unit 2 time. The neotenic Cypraeid genus *Calusacypraea* (Petuch, 1996) remained isolated in Myakka throughout Pinecrest and Fruitville times.

Fruitville (Unit 2) Kissimmee River Valley Equivalent

In the east, as in Myakka, the receding sea levels resulted in widespread intertidal shoals forming with the greatest concentration along the western side of the embayment. Dense, thick beds of the scallop *Carolinapecten bertiensis* (Mansfield, 1946) formed along the deeper open sand patches adjacent to the east of the shoals. Sea grass beds were interspersed with the scallop beds and these formed the preferred habitat for the Unit 2 equivalent Cypraeidae, which have been collected along the same strata as the *Carolinapecten*, *e.g.* at Rucks Pit, and further south along the Kissimmee River Valley.

During Unit 2 equivalent time, a series of narrow cuts across the St. Lucie Peninsula connected the northern end of the embayment with the Atlantic Ocean. These cuts formed cooler water corridors for the invasion of contemporaneous Virginia and Carolinas Chowan River Formation (Edenhouse Member) molluscan fauna into the embayment, including *Carolinapecten bertiensis*. The invasive fauna settled at the northern end of the embayment and were unable to move further south. While marine conditions were cooler, they were still able to support the last remaining Cypraeidae populations.

Immokalee Reef Tract (Unit 2)

The degradation of the coral reefs in the Immokalee Reef Tract, specifically those in Lee and Collier Counties, began in Unit 2 time and continued into the succeeding Fordville Member, Caloosahatchee Formation. The degradation process resulted in the depositional environment staying constant throughout. As a result, Unit 2 and Fordville Immokalee Reef Tract sediments in the present day appear the same. This was the result of the intertonguing of these two laterally adjacent (next to each other) strata facies. In other words, the carbonate facies of the Fordville-aged reefs intertongue with the subjacent carbonate facies of the upper Immokalee Reef Tract (Unit 2) of the Golden Gate Member. As these sediments are close to the surface, their mining tends to intermingle the two strata. As a result, the present placement of the of the Cypraeidae species into either Unit 2 or the Fordville Member reef sediments should be considered provisional.

Unit 2 Ends, First Stage Wounding Event

The end of Unit 2 signaled the commencement of a two stage sequential extinction event (Petuch, 1995, pp. 275-277). The first stage was a wounding event caused by the abrupt cooling of sea waters and the accompanying drop of water levels. Cooling temperatures and lower sea levels reached their nadir at the end of Unit 2 time, c. 2.65 mya. This event was characterized by the degradation of the extensive coral reef tracts that outlined the Everglades Pseudoatoll as well as the reduction of a great number of sea grass beds, mud flats and mangrove forests. By the end of Unit 2 time, the marine environments of southern Florida had become landlocked with the center of the Everglades Pseudoatoll becoming a landlocked salt water lake surrounded by degrading reef tracts.

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Extinction

At this time, the *Akleistostoma* (Gardner, 1948), *Calusacypraea* (Petuch, 1996) and *Pseudadusta* (Petuch, 2004) genera became extinct while three Cypraeidae genera, *Siphocypraea* Heilprin, 1886, the related *Pahayokea* (Petuch, 2004) and *Okeechobea* Petuch, 2004 survived this wounding event in the estuarine environments of southern Florida. These Cypraeidae populations, especially *Siphocypraea*, did survive, rebound and radiate in southern Florida during the early Gelasian Pleistocene, a period of modest warming. However, ecological habitats and populations were not fully restored before a second extinction occurred. Coupled with the wounding event, this second extinction event resulted in the mass extinction of all remaining Cypraeidae populations. This occurred at the end of the Gelasian Age, Early Pleistocene, c. 1.8 mya, with the return of cooling waters and dropping sea levels. (Petuch, 1995 and 2004).

Fruitville Member Species – Unit 2

Myakka Lagoon System (Sarasota)

Akleistostoma adrienae Petuch and Drolshagen, 2011 (Figure 1A)
Akleistostoma (Mansfieldicypraea) ivyi Petuch and Drolshagen, 2011 (Figure 1B)
Siphocypraea janowskyi Petuch and Drolshagen, 2011 (Figure 1C)
Siphocypraea (Seminolecypraea) alligator Petuch, 1994 (Figure 1E)
Calusacypraea loxa Petuch and Drolshagen, 2011 (Figure 1G)
Calusacypraea (Myakkacypraea) schnireli Petuch, 2004 (Figure 1D)
Pseudadusta marilynae (Petuch, 1994) (Figure 1H)
Pseudadusta yingsti Petuch and Drolshagen, 2011 (Figure 1F)
Pseudadusta (Bithloa) juyingae Petuch and Drolshagen, 2011 (Figure 1I)
Pseudadusta (Bithloa) gumbinneri Petuch and Drolshagen, 2011 (Figure 1J)

Kissimmee Embayment (Kissimmee River Valley restricted) Unit 2 equivalent

Akleistostoma (Ingramicypraea) ingrami (Petuch and Drolshagen, 2011) (Fig. 2A) ++
Akleistostoma (Ingramicypraea) glennae Petch and Drolshagen, 2011 (Figure 2B)
Akleistostoma (Olssonicypraea) zahinai Petuch and Drolshagen, 2011 (Figure 2G)
Pahayokea mauriceguyi Petuch, Berschauer and Myers, 2018 (Figure 2C)
Pahayokea (Kissimmecypraea) lybrandi Petuch and Drolshagen, 2011 (Figure 2D)
Okeechobea fortdrumensis Petuch and Drolshagen, 2011 (Figure 2E)
Okeechobea (Yeehawcypraea) lindajoyceae Petuch and Drolshagen, 2011 (Figure 2F)

Immokalee Reef Tract (Unit 2)

Siphocypraea (Lokossea) daughenbaughi Berschauer and Waller, 2020 (Figure 2H) *

Altogether, 18 species in seven genera have been collected in Unit 2 deposits.

* **NOTE:** The assignment of this species to Unit 2 time and the reclassification and reassignment of *Siphocypraea (Lokossea) dimasi* Petuch, 1998 to Unit 3 time is provisional.

Siphocypraea dimasi is reclassified and reassigned from its present uncertain placement in either Unit 2 or the Fordville Member into Unit 3 as the first and oldest species of the *Siphocypraea (Lokossea)* Petuch and Drolshagen, 2011 subgenus. The subgenus features include "large, inflated, rotund species with very tightly coiled apical sulci". However, with the addition of these two species, the subgenus is revised to include variably shaped species which are slightly inflated/inflated with tightly coiled apical sulci, long thin columellar dentition, which extends deep into the aperture and labral dentition, which extends well

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onto/over the base, forming corrugations. The latter are obvious on some species while eroded on others or hidden by callus. The corrugations in most specimens are visible under black light.

When first described, *S. dimasi* was only known from the back reef lagoon environment, adjacent to the corals of the Immokalee reefs at the old Mule Pen Quarry at Naples, Florida. It was placed in Unit 3 based upon its similarity to *Siphocypraea cannoni* Petuch, 1994 from the Sarasota quarries. Subsequent collecting produced a few specimens from the Sarasota quarries, suggesting it is exceedingly rare. While *S. dimasi* was similar to *S. cannoni*, its size, more slender shape and more coiled apical sulcus separated these two species. The species shared strong labral corrugations; a feature also shared with *S. (L.) daughenbaughi* and all other species of the subgenera. Based on morphological features, the species is returned to its initial Unit 3 assignment.

The assignment of *S. (L.) daughenbaughi* to Unit 2 of the Immokalee reef tract is also provisional. As set forth above, the reef tract facies intertongue, which along with the mining of the facies, makes it impossible to definitively assign a specific Unit time. However, based upon morphological features, it is placed in Unit 2 time as the successor to *S. dimasi* and predecessor to *Siphocypraea (Lokossea) mulepenensis* Petuch, 1991, the latter provisionally assigned to the Fordville Member. (See Berschauer and Waller, 2020).

[++] **Reclassification**

Based on a resemblance to the older, Unit 3 *Akleistostoma rilkoi* (Petuch, 1998) of the Myakka Lagoon System, *Akleistostoma ingrami* was originally classified as the only Kissimmee *Akleistostoma* species in the *Akleistostoma* genus. However, the species actually bears a closer resemblance to certain specimens of the Unit 4 subgenus species *Akleistostoma (Ingramicypraea) cliffordi* Petuch and Drolshagen, 2011. The only difference appears in the shape of the specimens. As set forth previously (Daughenbaugh, Unit 4 and 3, 2019, 2020), Kissimmee was separated from Myakka by the massive Polk Peninsula and lacked any viable means of transport between the two areas. Based on the separation as well as the likely presence of an ancestor in the Kissimmee, the species is reclassified as *Akleistostoma (Ingramicypraea) ingrami* (Petuch and Drolshagen, 2011).

Origins

At Sarasota, both *A. adrienae* and *A. (M.) ivyi* appear to be offshoots of *Akleistostoma (Mansfieldicypraea) juliagardnerae* Petuch and Drolshagen, 2011. *Siphocypraea janowskyi* is probably descended from *Siphocypraea cannoni* Petuch, 1994 while *S. (S.) alligator,* the last species of the subgenus, resembles a more rostrate *Siphocypraea (Seminolecypraea) parodizi* Petuch, 1994. Occurring together at Sarasota, *C. loxa* and *C. (M.) schnireli* are the last species of the genus and subgenus. They resemble their immediate ancestors. The former resembles *Calusacypraea sarasotaensis* (Petuch, 1994) but is a more elongate shell with a much narrower aperture. The latter resembles a more truncated version of *Calusacypraea (Myakkacypraea) kelleyi* (Petuch, 1998). Both *P. marilynae* and *P. yingsti* appear to be offshoots of *Pseudadusta ketteri* (Petuch, 1994) while both *P. (B.) juyingae* and *P. (B.) gumbinneri* appear to be offshoots of *Pseudadusta (Bithloa) kalafuti* (Petuch, 1994).

At Kissimmee, the ancestor of *A. ingrami* is uncertain (see above). There are two variations of *A. (O.) glennae*. Both resemble *Akleistostoma (Olssonicypraea) diegelae* (Petuch, 1994), the

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smaller resembles a more callous variation and the larger a more callous and deltoidal variation. *Akleistostoma (Olssonicypraea) zahinai* resembles its immediate ancestor, *A. (O.) diegelae*. The Unit 3 equivalent *Pahayokea penningtonorum (*Petuch, 1994) precedes the younger *P. mauriceguyi*, a more cylindrical, blunter shell. *Pahayokea (Kissimmecypraea) lybrandi* is a slenderer version of the large variation of *Pahayokea (Kissimmecypraea) leonardi* Petuch and Drolshagen, 2011 with finer columellar teeth. The ancestors of both *O. fortdrumensis* and *O. (Y.) lindajoyceae* are uncertain as no species of either the genus or subgenus have been recorded from Unit 3 equivalent.

In the Immokalee Reef Tract, *S. (L.) daughenbaughi* is the likely successor to *S. (L.) dimasi*. The latter has no known ancestor.

For detailed genera and species descriptions, background information and discussion, see *Jewels of the Everglades, The Fossil Cowries of Southern Florida*, 2018, by Edward J. Petuch, David P. Berschauer and Robert F. Myers.

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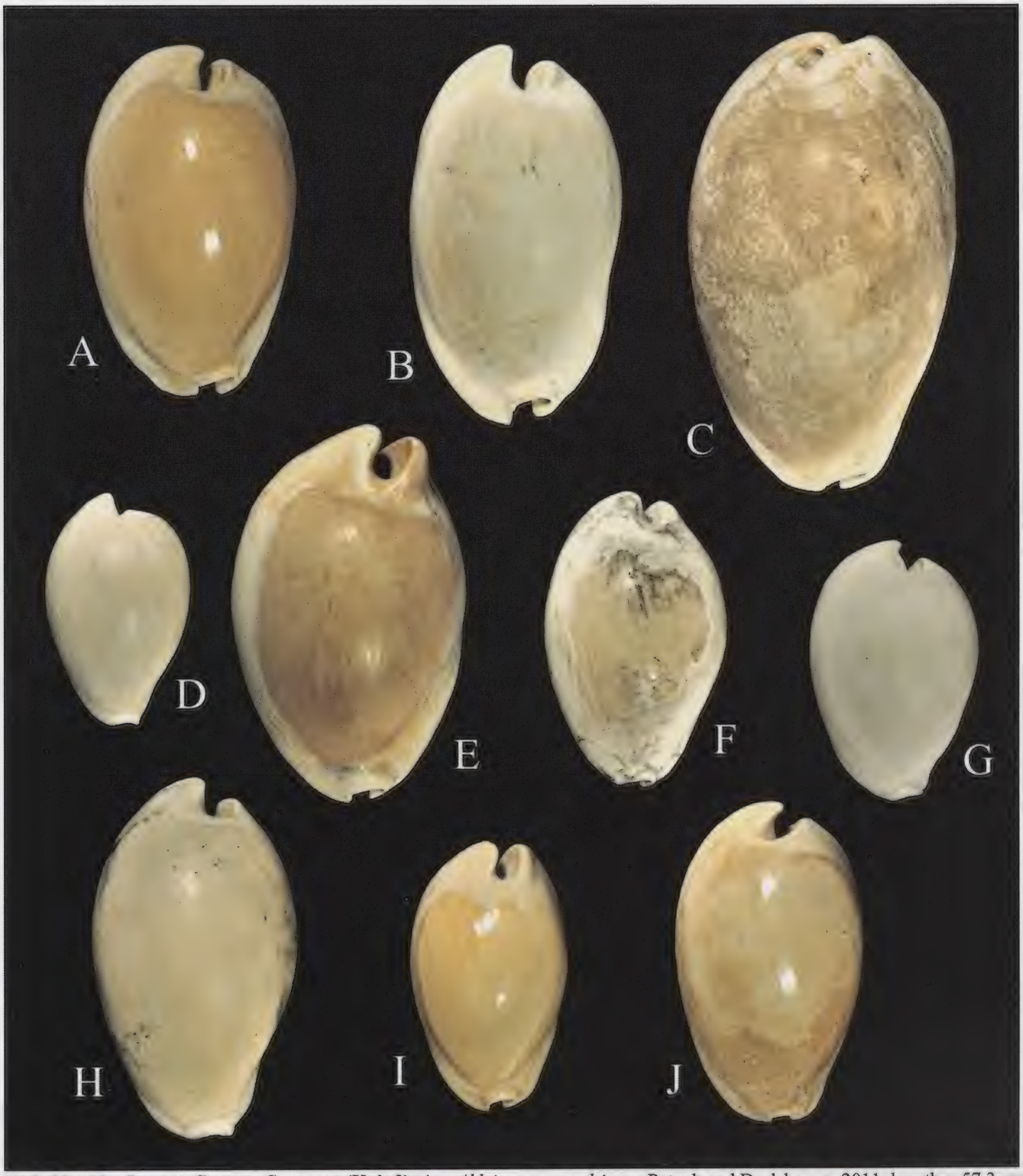

Figure 1. Myakka Lagoon System, Sarasota (Unit 2). A = *Akleistostoma adrienae* Petuch and Drolshagen, 2011, length = 57.3 mm; **B** = *Akleistostoma (Mansfieldicypraea) ivyi* Petuch and Drolshagen, 2011, length = 61.9 mm; **C** = *Siphocypraea janowskyi* Petuch and Drolshagen, 2011, 74.7 mm; **D** = *Calusacypraea (Myakkacypraea) schnireli* (Petuch, 2004), length = 38.0 mm; **E** = *Siphocypraea (Seminolecypraea) alligator* (Petuch, 1994), length = 62.3 mm; **F** = *Pseudadusta yingsti* Petuch and Drolshagen, 2011, length = 48.1 mm; **G** = *Calusacypraea loxa* Petuch and Drolshagen, 2011, length = 42.2 mm; **H** = *Pseudadusta marilynae* (Petuch, 1994), length = 58.4 mm; **I** = *Pseudadusta (Bithloa) juyingae* Petuch and Drolshagen, 2011, length 45.0 mm; **J** = *Pseudadusta (Bithloa) gumbinneri* Petuch and Drolshagen, 2011, length = 50.0 mm.

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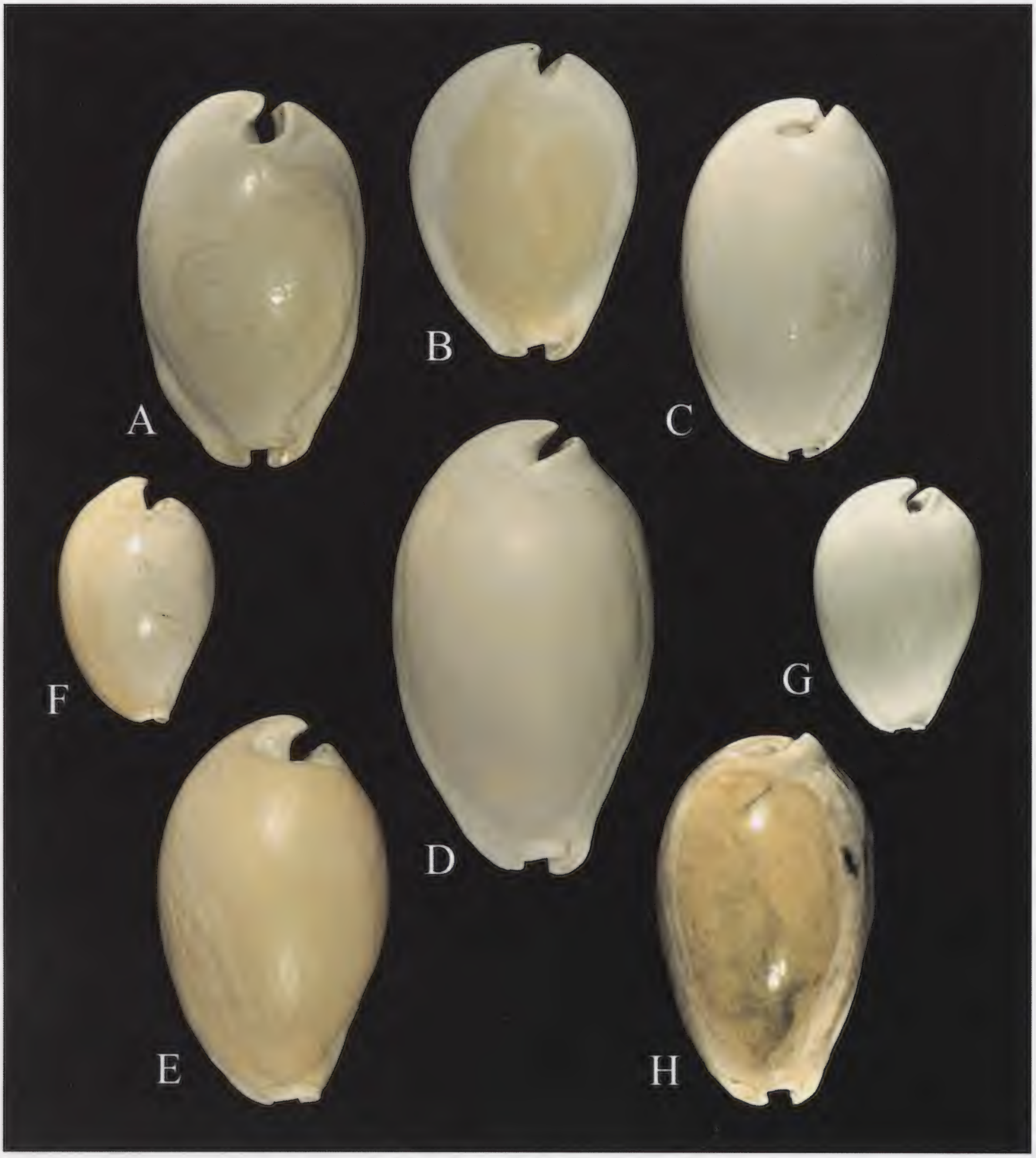

Figure 2. Kissimmee River Valley (Unit 2 equiv.) A-G, Bonita Springs H. A = *Akleistostoma ingrami* Petuch and Drolshagen, 2011, length = 56.2 mm; **B** = *Akleistostoma (Ingramicypraea) glennae* (Petuch and Drolshagen, 2011), length = 46.5 mm; **C** = *Pahayokea mauriceguyi* Petuch, Berschauer and Meyers, 2018, length = 53.1 mm; **D** = *Pahayokea (Kissimmecypraea) lybrandi* Petuch and Drolshagen, length = 66.9 mm; **E** = *Okeechobea fortdrumensis* Petuch and Drolshagen, 2011, length = 57.0 mm; **F** = *Okeechobea (Yeehawcypraea) lindajoyceae* Petuch and Drolshagen, 2011, length = 36.4 mm; **G** = *Akleistostoma (Olssonicypraea) zahinai* Petuch and Drolshagen, 2011, length = 37.9 mm; **H** = *Siphocypraea* (*Lokossea*) *daughenbaughi* Berschauer and Waller, 2020, length = 63.2 mm.